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Issued May 31, 1910.

U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 123.

A. D. MELVIN, CHIEF OF BUREAU.

THE INFLUENCE OF LACTIC ACID ON THE QUALITY  
OF CHEESE OF THE CHEDDAR TYPE.

BY

*Doane*  
C. F. DOANE,

*Assistant Dairyman, Dairy Division.*



WASHINGTON:  
GOVERNMENT PRINTING OFFICE.  
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## LETTER OF TRANSMITTAL.

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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF ANIMAL INDUSTRY,  
*Washington, D. C., March 14, 1910.*

SIR: I have the honor to transmit the accompanying manuscript of an article entitled "The Influence of Lactic Acid on the Quality of Cheese of the Cheddar Type," by C. F. Doane, of the Dairy Division of this Bureau. Mr. Doane has for some time been stationed at one of the principal cheese-making centers of the country, carrying on work connected with the manufacture and storage of cheese under practical conditions. The experiments described in the present paper have resulted in establishing data which are contrary to the usual practice of factories producing the Cheddar type of cheese, and are therefore calculated to be of value to this section of the cheese-making industry. I recommend the publication of the article in the bulletin series of this Bureau.

Very respectfully,

A. D. MELVIN,  
*Chief of Bureau.*

HON. JAMES WILSON,  
*Secretary of Agriculture.*

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# THE INFLUENCE OF LACTIC ACID ON THE QUALITY OF CHEESE OF THE CHEDDAR TYPE.

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## INTRODUCTION.

The relation of lactic acid to the science of cheese making, particularly its action under varying conditions, and the necessity, or otherwise, for its development during the process of manufacture, are among the greatest unsolved problems connected with the dairy industry.

In the making of the Cheddar type of cheese at the present time the expert cheese maker is chiefly concerned with this development of lactic acid, and his entire ability is exerted to secure a uniformity of cooking with the development of the acid. This is desired because it is believed that a maximum quantity of acid is necessary for the best results. This maximum development is determined by the amount of acid that the curd will stand in the whey at the time of drawing the latter without subsequent injury to the texture and the color of the cheese. The best cheese makers are agreed, almost without exception, that on this development of acid depends to a great extent the delicate flavor that the best cheese should have, also, the desired closeness of body, as well as some of the qualities of texture found in the best cheese. Under the present conditions, therefore, there is ample opportunity for the exhibition of skill in handling the milk and the curd, since the attainment of even a small degree of success in securing uniformity of the different processes under varying conditions comes only with long practice and keen observation.

## LACTIC-ACID PROBLEMS IN CHEESE MAKING.

There is undoubtedly much yet to be learned concerning the development of lactic acid and its effects in cheese making. One apparent inconsistency lies in the differing effects of the lactic acid which is developed before, as compared with that which is developed after, the whey is drawn. It is well known that the development of acid in the whey beyond approximately 0.2 per cent will

result in an acid cheese, although a slight variation from this will depend upon whether the milk is working fast or slow. A high-acid condition has a decidedly injurious effect on the texture and the color of the cheese, and the greater the development of acid in the whey beyond the above limit the more pronounced is the injury. On the other hand, after the whey is drawn and the curd is put on the rack, the acid may develop until the expressed whey shows a full 1 per cent, or even more, without any injury to texture or color. This would certainly appear to be inconsistent. In both cases the acid formed is evidently lactic acid. In both cases the acid is formed inside of the curd particles, as the greater part of the bacteria are carried down into the curd after setting the milk and cutting the curd,<sup>a</sup> and the acid is formed in the curd and expelled into the whey. We have, then, in each case a process of acid formation operating under such similar conditions as to be apparently identical, yet the results are radically different. While in the whey a development of 0.3 per cent of lactic acid will practically ruin the commercial value of the cheese, yet in the matted curd more than three times this quantity may develop with what most cheese makers believe to be a benefit, and certainly without apparent injury.

In the best present-day practice in cheese making there is an attempt to develop all the acid possible without injury to the texture and color of the product. To begin with, a maximum amount of acid is developed in the whey, and finally the curd is allowed to remain on the rack until all the acid that will develop in a practicable length of time is obtained. But while there are many positive opinions in regard to the good results of this method, there is but little accurate knowledge. The effect of acid on flavor is not known, and, contrary to general opinion, a glance at some of the tables included in this paper will show that a flat or low flavor may be found in a high-acid cheese. Again, the actual effects of a so-called proper development of acid on the closeness or the texture of the cheese is not known. The desired characteristics of texture, body, and flavor may be found, and have been found on numberless occasions, when the curd has been worked through comparatively sweet.

However, we know beyond doubt that a high acid development in the whey will injure the resulting product. Furthermore, we have very good reason to believe that a high acid development in the curd made from so-called gassy milk is necessary to overcome the gas, and it may at the same time prevent a full development of the undesirable flavors attending gassy curds.

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<sup>a</sup>J. L. Sammis. Factors controlling the moisture content of cheese curds. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 122.

TABLE 1.—Details of storage experiments showing inferiority of high-acid cheese.

No. of cheese.	Storage temperature $\alpha$ and age of cheese when stored.	Numerical score.				Descriptive score.			
		Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.	Color.
1N2	32° room, at once.	21½	19½	7	10	57½	Tainted, sweet.	Curdy, stiff	Mottled.
2N1	Ripened in curing room	23½	19½	11½	10	64	Acid faint.	Pasty, loose	Acid cut.
2N2	32° room, at once	22½	19½	8	10	60½	Sour.	Stiff, gritty	Do.
2N3	40° room, at once	24	20	9	10	64½	do.	do.	Do.
3N2	32° room, at once	26	24	12	10	72	Fruity	Short, salty	Do.
3O2	32° room, 1 week	23	19	13	10	65	Tainted	Curdy, short.	Do.
4N3	40° room, at once	27½	25	14	10	76½	Fruity, flat.	Salvy	Do.
4O2	32° room, 1 week	28½	24½	12	10	74½	do.	do.	Do.
5N2	32° room, at once	37	26½	15	10	89	Sweet.	do.	Straight.
5O2	40° room, 1 week	36½	24½	15	10	85½	Sweet, tainted.	Mealy, loose	Do.
6N2	40° room, 1 week	34	22	15	10	78	Tainted, bitter.	Salvy	Acid cut.
7N2	32° room, at once	31	22	15	10	84	do.	Smooth	Do.
7O3	40° room, 1 week	35	24	15	10	84	Tainted, barn	do.	Straight.
8N2	32° room, at once	32½	26½	15	10	84½	Tainted, slightly	do.	Do.
8N3	40° room, at once	32	26½	15	10	83½	do.	do.	Do.
9O3	32° room, 1 week	36½	26	15	10	87½	Sweet.	Gritty	Acid cut.
9N2	40° room, at once	33½	22½	15	10	80½	do.	Weak	Do.
9O2	32° room, 1 week	31	24	15	10	80	do.	Mealy	Do.
10N2	40° room, at once	32½	21½	8½	10	73½	Tainted, weedy	do.	Do.
10N3	32° room, at once	32	22	8½	10	72½	Bitter	do.	Do.
10O2	40° room, 1 week	32	23½	9½	10	75	Sweet, bitter	do.	Do.
10N3	32° room, at once	29½	24	13½	10	76½	Tainted	Short, weak	Do.
10O2	40° room, 1 week	31½	24	12	10	77½	do.	do.	Do.
11N2	32° room, at once	30	22½	10½	10	73½	do.	Coarse	Do.
11O2	32° room, 1 week	37½	26	15	10	88½	Weedy, flat	Gritty	Do.
11N3	40° room, at once	37	24	15	10	86½	Acid faint	do.	Do.
11O3	32° room, 1 week	40½	29½	14	10	94	Flat	do.	Do.
12N2	32° room, at once	36½	24½	15	10	85½	Cowly, weedy	Smooth	Straight.
12N3	40° room, at once	36	26½	15	10	87½	Sweet, cowly	Gritty	Acid cut.
12O2	32° room, at once	33½	24½	13½	10	81½	do.	do.	Do.
12O3	40° room, 1 week	36½	25	15	10	86½	Sweet.	do.	Do.
13N2	40° room, 1 week	29	24½	13	10	77	do.	do.	Do.
13N3	32° room, at once	30½	26	12½	10	79½	Tainted	Smooth	Straight.
13O2	40° room, at once	32	24½	15	10	81½	Tainted, cowly	Loose	Acid cut.
13O3	32° room, 1 week	33½	25½	13½	10	82½	Tainted	do.	Do.
14O3	40° room, 1 week	32½	25	15	10	83½	do.	do.	Do.
14N2	32° room, at once	30	25	15	10	80	Tainted, flat	Tallowy	Straight.

<sup>a</sup> Temperatures Fahrenheit.

TABLE 1.—Details of storage experiments showing inferiority of high-acid cheese—Continued.

No. of cheese.	Storage temperature $\alpha$ and age of cheese when stored.	Numerical score.				Descriptive score.			
		Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.	Color.
14N3...	40° room, at once.	28	22	12	10	73	Tainted.	Salvy, mealy.	Acid cut.
14O2...	32° room, 1 week.	32	24	14	10	81	Tainted, bitter.	do.	Do.
14O3...	40° room, 1 week.	31	25	14	10	80	Sweet, tainted.	Weak, smooth.	Do.
15N2...	32° room, at once.	31	26	15	10	82	Sweet.	do.	Do.
15N3...	40° room, at once.	28	25	15	10	76	Bitter, sweet.	Weak, mealy.	Acid cut.
15O2...	32° room, 1 week.	29	27	11	10	77	Tainted, flat.	Pasty.	Straight.
16J2...	32° room, immediately.	31	23	14	10	79	do.	Short.	Do.
16K3...	40° room, immediately.	28	23	14	10	77	Tainted.	Short, mealy.	Acid cut.
16K2...	32° room, 4 days.	27	22	11	10	66	Bitter, sour.	do.	Do.
16K3...	40° room, 4 days.	26	20	10	10	68	Tainted, sour.	do.	Do.
16L2...	32° room, 1 week.	26	21	11	10	68	do.	do.	Do.
16L3...	40° room, 1 week.	26	21	11	10	68	do.	do.	Do.
16M2...	32° room, 2 weeks.	27	22	13	10	72	do.	do.	Do.
16M3...	40° room, 2 weeks.	28	22	13	10	71	do.	do.	Do.
17J2...	32° room, at once.	29	25	14	10	78	Tainted.	Stiff.	Do.
17J3...	40° room, at once.	29	21	10	10	70	do.	do.	Wavy.
17M3...	40° room, 2 weeks.	26	20	13	10	70	do.	do.	Mottled.
18J2...	32° room, at once.	35	26	15	10	86	Flat.	Smooth, stiff.	
18J3...	40° room, at once.	35	27	15	10	88	Flat, sour.	Smooth.	
18L2...	32° room, 1 week.	35	25	15	10	86	Flat.	do.	
18L3...	40° room, 1 week.	34	26	15	10	83	Sweet, sour.	Smooth, stiff.	
18M3...	32° room, 2 weeks.	32	24	15	10	81	Sweet, tainted.	Stiff, gritty, Swiss holes.	
19J2...	40° room, at once.	31	27	15	10	83	Flat, low.	Mechanical holes.	
19J3...	32° room, at once.	31	25	15	10	81	Flat, tainted.	Smooth, stiff.	
19L3...	40° room, at once.	30	23	15	10	78	Tainted, cowy.	Pasty.	Acid cut.
19M3...	32° room, 2 weeks.	27	24	14	10	76	Sweet, tainted.	Stiff, gritty.	Do.
20J2...	40° room, at once.	32	25	15	10	82	Flat.	Stiff.	
20J3...	32° room, at once.	26	22	15	10	73	Tainted.	do.	
20L2...	40° room, 1 week.	27	23	13	10	75	do.	Lumpy, stiff.	Do.
20M3...	32° room, 2 weeks.	25	23	13	10	71	do.	Stiff.	
21J2...	40° room, at once.	35	27	15	10	87	do.	Stiff, smooth.	
21J3...	32° room, 1 week.	34	26	15	10	86	Tainted, flat.	do.	
21L2...	40° room, 2 weeks.	31	25	15	10	83	do.	Smooth.	Straight.
21M3...	32° room, 2 weeks.	31	27	15	10	84	Flat.	Smooth, stiff.	Acid cut.
22J2...	40° room, at once.	36	27	15	10	85	do.	Mealy, stiff.	Do.
22L2...	32° room, 1 week.	34	26	15	10	79	Tainted.	Mealy.	Do.
22L3...	40° room, 1 week.	31	24	14	10	76	do.	do.	Do.
22M3...	40° room, 2 weeks.	30	23	9	10	75	do.	do.	Do.

2212	32° room, at once.	27.3	13	10	71.2	Acid, badly tainted.	do	Do.
2213	40° room, 2 weeks.	24	11	10	63	do	do	Do.
2214	32° room, at once.	26.3	12	10	75.1	Acid tainted.	do	Do.
2412	32° room, 2 weeks.	29	13	10	75.2	do	do	Do.
2413	40° room, 2 weeks.	26	10	10	66.2	do	do	Do.
2512	32° room, at once.	29.1	14	10	72.3	Bitter, flat.	do	Do.
2513	40° room, at once.	26	9	10	66.3	Bitter, tainted.	do	Do.
2514	32° room, 1 week.	26	10	10	66.4	Acid, tainted.	do	Do.
2515	40° room, 2 weeks.	22	8	10	58	do	do	Do.
2516	32° room, at once.	34.1	14.1	10	85	Tainted, flat.	Stiff, smooth.	Do.
2612	32° room, 4 days.	33	15	10	81	Tainted, flat.	do	Do.
2613	40° room, 4 days.	32.1	14.1	10	84	Tainted.	Stiff, curdy.	Do.
2614	32° room, 1 week.	35	15	10	82.1	do	Stiff, tough.	Do.
2615	40° room, 2 weeks.	30.1	15	10	80.1	do	Tough.	Do.
2616	32° room, 2 weeks.	23	15	10	70.2	Badly tainted.	Stiff, tough.	Do.
2617	40° room, at once.	29.2	10.1	10	74	do	Stiff.	Do.
2712	32° room, at once.	29	9	10	60	Sour, tainted.	Short, mealy.	Wavy.
2713	40° room, 4 days.	23.1	9	10	63	do	do	Do.
2714	32° room, 4 days.	23.2	9	10	63	do	do	Do.
2715	40° room, 4 days.	23.3	10	10	66	do	do	Do.
2716	32° room, 1 week.	25.2	10	10	66	do	do	Do.
2717	40° room, 2 weeks.	21.2	9	10	63.1	Sour, badly tainted.	do	Do.
2718	32° room, 2 weeks.	20	19	10	58	do	do	Do.
2812	32° room, at once.	14.1	7	10	52.1	do	do	Do.
2813	40° room, at once.	23	11	10	72	Sour, flat.	do	Do.
2814	32° room, 4 days.	27.1	12	10	72.2	do	do	Do.
2815	40° room, 4 days.	26	10	10	70.1	Acid.	do	Do.
2816	32° room, 1 week.	26.1	10	10	69	Acid, tainted.	do	Do.
2817	40° room, 1 week.	27.1	11	10	70	do	do	Do.
2818	32° room, 1 week.	23.1	10	10	69.1	do	do	Do.
2819	40° room, 2 weeks.	24	10	10	64	do	do	Do.
2820	32° room, 2 weeks.	28	15	10	64	Acid, tainted, bitter.	Loose, gas holes.	Do.
2821	40° room, at once.	25	15	10	77	Tainted, sweet.	Gas holes.	Do.
2912	32° room, 4 days.	25.3	15	10	75.1	Sweet, bitter.	Sweet.	Do.
2913	40° room, 4 days.	24.1	15	10	71.1	Sweet, tainted.	do	Do.
2914	32° room, 1 week.	26.2	15	10	73.1	do	do	Do.
2915	40° room, 1 week.	26.3	15	10	74.1	do	do	Do.
2916	32° room, 2 weeks.	23	15	10	69.1	do	do	Do.
2917	40° room, 2 weeks.	23.1	15	10	69.2	do	do	Do.
2918	32° room, at once.	33	15	10	83	Tainted, flat.	Smooth.	Do.
2919	40° room, at once.	31.1	15	10	83	do	Stiff.	Do.
3012	32° room, 4 days.	29	15	10	79.1	do	do	Do.
3013	40° room, 4 days.	29	15	10	80.1	do	do	Do.
3014	32° room, 1 week.	28	15	10	75.1	do	Gas holes.	Do.
3015	40° room, 1 week.	28.1	15	10	77.1	do	do	Do.
3016	32° room, 2 weeks.	29	15	10	79	Tainted.	do	Do.
3017	40° room, 2 weeks.	26	15	10	75	do	do	Do.
3112	32° room, at once.	33	15	10	84.1	Tainted, flat.	Mechanical holes.	Do.
3113	40° room, at once.	30.1	15	10	81.1	do	do	Do.

a Temperatures Fahrenheit.

TABLE 1.—*Details of storage experiments showing inferiority of high-acid cheese—Continued.*

No. of cheese.	Storage temperature <sup>a</sup> and age of cheese when stored.	Numerical score.				Descriptive score.		
		Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.
31K2	32° room, 4 days.	31	27½	15	10	83½	Tainted, flat.	Smooth, mechanical holes.
31K3	30° room, 1 week.	28½	25	15	10	78½	do.	Gritty, mechanical holes.
31L2	32° room, 1 week.	28	25	15	10	78	do.	do.
31L3	30° room, 1 week.	26	24	15	10	76½	do.	Gritty, gas holes.
31M2	32° room, 2 weeks.	26	25	15	10	76	do.	do.
31M3	30° room, 2 weeks.	24	25	15	10	74	do.	do.
32L2	32° room, 1 week.	26	25	15	10	76	do.	do.
32L3	40° room, 1 week.	26	25	15	10	76	do.	do.
32M2	32° room, 2 weeks.	25	23	10	10	68	Tainted, flat.	Gas holes, smooth.
32M3	40° room, 2 weeks.	26	24	12	10	72	do.	Short.
33L2	32° room, 1 week.	26	24	12	10	72	do.	do.
33L3	40° room, 1 week.	26	24	12	10	72	do.	do.
33M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
33M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.
34L2	32° room, 1 week.	26	24	12	10	72	Tainted, bitter	do.
34L3	40° room, 1 week.	26	24	12	10	72	Tainted, bitter, flat.	do.
34M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
34M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.
35L2	32° room, 1 week.	26	24	12	10	72	do.	do.
35L3	40° room, 1 week.	26	24	12	10	72	do.	do.
35M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
35M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.
36L2	32° room, 1 week.	26	24	12	10	72	do.	do.
36L3	40° room, 1 week.	26	24	12	10	72	do.	do.
36M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
36M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.
37L2	32° room, 1 week.	26	24	12	10	72	do.	do.
37L3	40° room, 1 week.	26	24	12	10	72	do.	do.
37M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
37M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.
38L2	32° room, 1 week.	26	24	12	10	72	do.	do.
38L3	40° room, 1 week.	26	24	12	10	72	do.	do.
38M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
38M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.
39L2	32° room, 1 week.	26	24	12	10	72	do.	do.
39L3	40° room, 1 week.	26	24	12	10	72	do.	do.
39M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
39M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.
40L2	32° room, 1 week.	26	24	12	10	72	do.	do.
40L3	40° room, 1 week.	26	24	12	10	72	do.	do.
40M2	32° room, 2 weeks.	25	23	10	10	68	do.	do.
40M3	40° room, 2 weeks.	25	23	10	10	68	do.	do.

1. The cheeses which had too much acid are noted as "acid cut" in the column headed "Color."

2. The first figure in the number of the cheese indicates the lot or vat.

<sup>a</sup> Temperatures Fahrenheit.

**EFFECT OF HIGH ACIDITY ON QUALITY OF STORAGE CHEESE.**

The attention of the writer was called to one phase of this acid question at the time of scoring the cheese in the storage experiments made in the summer of 1906. A representative of the Dairy Division visited a number of cheese factories near Plymouth, Wis., that were having trouble with their product, and secured a quantity of cheese for storage. Most of these lots of cheese turned out to be high acid, and it was noted that where this was the case the quality was so very low as to make it appear that the acid was responsible in part at least for the poor flavor, as well as for the other undesirable characteristics always found in a high-acid cheese.

The cheese in question was obtained for the purpose of determining the effect of storage on different kinds of poor cheese. It was purchased in July and August and was scored in January. The scores are given in Table 1. Because of the large proportion of this cheese that turned out to be high acid the work as planned was not satisfactory, but it did show the tendency to make high-acid cheese when troubles with bad milk are experienced, and it illustrated very well the probable effect of high acid on the quality of the product. There were 34 lots of the cheese, each consisting of 8 cheeses, one-half of which were stored in the 32° F. room at various periods ranging up to two weeks, the other half being similarly placed in the 40° F. room. The average score on flavor for the high-acid cheese was 27, while the average on the normal acid cheese was 31. The comparatively poor flavor of all the high-acid cheese was so marked that all who were connected with the scoring of this cheese noticed it and commented upon it.

The Dairy Division made some high-acid cheese in the summer of 1906 to determine the effects of storage on this quality of product. The cheese was made from exceptionally good milk, and the flavor should have been, in some of the lots at least, above criticism. Nine lots of cheese were made with varying amounts of acid. Quite a wide variation in the percentages of acid was sought, especially at the time the whey was drawn, as the degree of acidity at this period influences the quality of the cheese more than the acidity shown at any other period of its manufacture. The acid at the time of setting was regulated to suit the percentage desired at the time of drawing the whey. The percentages of acid at different stages of manufacture are shown in Table 3.

Eight cheeses were made in each lot. These were stored two at a time—one at 32° F. and the other at 40° F.—at each of the following periods: Fresh from the press, four days old, one week old, and two weeks old. All the cheese was scored by three judges working independently, and Table 2 gives the average scores. Table 4, abstracted

TABLE 2.—Average scores of cheese, showing influence of high acid.

No. of cheese.	Storage temperature <sup>a</sup> and age of cheese when stored.	Numerical score.				Descriptive score.		
		Flavor (Max. 45).	Texture (Max. 30).	Color (Max. 15).	Make-up (Max. 10).	Total (Max. 100).	Flavor.	Texture.
1R2	39° room, at once.	31½	26½	14	10	82	Tainted, flat.	Smooth.
1R3	40° room, at once.	30	25½	14	10	80½	Flat, acid.	Gritty.
1S2	39° room, 4 days.	28½	24½	13	10	76	High acid, tainted.	Short, gritty.
1S3	39° room, 4 days.	27	24½	13	10	74½	Tainted, slight acid.	Soft, gritty.
1R4	39° room, 1 week.	26½	23½	12½	10	72½	Acid, tainted, sweet.	Crumby, mealy.
1R5	39° room, 1 week.	26	24	12	10	72	Acid, tainted.	Mealy, loose.
1U2	39° room, 2 weeks.	27½	24½	14	10	76	Tainted, acid.	Short, stiff.
1U3	39° room, 2 weeks.	26½	25	14	10	75½	Sharp, acid.	Soft, gritty.
2R2	39° room, at once.	24½	21	12	10	71½	Acid, tainted.	Soft, gritty.
2R3	39° room, 2 weeks.	24	21	10½	10	68½	do.	Pasty, gritty.
2R4	39° room, 2 weeks.	22½	21	11	10	65½	Acid, tainted.	Mealy, gritty.
3U2	39° room, at once.	22½	22½	11	10	66½	Acid, tainted.	Short, mealy.
3U3	39° room, 2 weeks.	22½	18½	9½	10	61½	Acid, tainted.	Short, mealy.
4R2	39° room, at once.	21½	17	7½	10	56½	Acid, faint, sour.	Short, mealy.
4R3	39° room, 2 weeks.	22½	18	8	10	58½	Acid, faint, sour.	Short, mealy.
5R2	39° room, at once.	22	18½	8	10	58½	Sour, acid.	Short, mealy.
5R3	39° room, 2 weeks.	22	14	5½	10	49½	Acid, faint, sour.	do.
6R2	39° room, at once.	18½	14	5	10	47½	Acid, faint.	Short, loose.
6R3	39° room, 1 week.	26	24	10	10	70	Acid, flat.	Pasty, weak.
7R2	39° room, 2 weeks.	25½	25	11	10	71½	Acid, faint.	Short, mealy.
7R3	39° room, at once.	25	25	11	10	71	do.	Mealy, gritty.
7U2	39° room, 1 week.	25½	23	10½	10	69½	Acid.	Pasty.
7U3	39° room, 2 weeks.	24½	23½	10½	10	68½	Acid, tainted.	Pasty, mealy.
8R2	39° room, at once.	24½	24	10½	10	71½	Acid.	Pasty, gritty.
8U2	39° room, 1 week.	24	24	12	10	70	do.	Pasty, mealy.
8U3	39° room, 2 weeks.	24½	21½	10½	10	66½	Sour, tainted.	Dry, mealy.
9R2	39° room, at once.	20½	24	10	10	64½	Acid, faint.	Dry, mealy.
9U2	39° room, 1 week.	25½	22	9	10	66½	Acid, sour.	Mealy, gritty.
9U3	40° room, 2 weeks.	24½	21½	9	10	65	Acid, tainted.	do.

The first figure indicates the lot; thus all cheeses with No. 1 came from the same vat.

<sup>a</sup> Temperatures Fahrenheit.



from Table 2, and figure 1 are arranged to show more clearly the relation of the numerical score to the acidity. Not all the scores are given, but those omitted are in line with those given. Enough are given to show conclusively the effect of the high acid on the cheese.

TABLE 3.—*Acidity at stated periods of high-acid cheese used in storage experiments and scored in Table 2.*

No. of lot.	Acidity when set.	Acidity when cut.	Acidity when drawn.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1.....	0.175	0.120	0.207
2.....	.175	.....	.229
3.....	.185	.....	.240
4.....	.195	.....	.215
5.....	.260	.184	.303
6.....	.200	.145	.225
7.....	.175	.....	.220
8.....	.182	.....	.211-
9.....	.170	.120	.220

TABLE 4.—*Relation of the numerical score to the acidity of cheese described in Table 2.*

Number of lot.	Acidity.	32° room, at once.			32° room, one week.			40° room, two weeks.		
		Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
	<i>Per ct.</i>									
1	0.207	31½	26½	82	26½	23½	72½	26½	25	75½
8	.211	27½	23½	71½	27	24	71½	24½	21½	67½
4	.215	25	22½	67	22½	18	58½	22	18½	58½
7	.220	26½	25	72½	25½	23	68½	26½	22½	68½
9	.220	26½	24	71	25½	22	66½	24½	21½	65
6	.225	28½	25½	74½	26	24	70	25	21½	65½
2	.229	26½	24½	72½	24½	23½	68½	26½	18½	63½
3	.240	23½	22½	67	23½	18½	61½	21½	17	56
5	.303	20	14	49½	.....	.....	.....	18½	14½	47½

It has already been stated that the above cheese was made as far as could be judged from perfect milk and that the curds worked through in excellent shape. At least a few cheeses should have been of excellent quality; but it appears that the quality was injured in about the same proportion as the amount of acid developed. The cheese in lot 1 was made with acid very slightly in excess of normal, and the cheese from this lot that was placed in the 32° room at once scored 82, while the similarly treated cheese in lot 5 was made with much too high a development of acid and scored a fraction less than 50. It is probable that cheese made from good milk would never score as low as 50 points or as low as 20 points in flavor if it had been treated normally in all stages of making and curing. Hence it would appear very probable that the high-acid development was responsible in part, at least, for the poor flavor. These results were so contrary to all belief and teaching that it was thought desirable to make some

accurate comparative tests that would settle the question beyond controversy. For this purpose the author spent some time at a factory near Plymouth, Wis., and carried out the experiments described in the following pages.

#### EXPERIMENTAL WORK TO TEST EFFECT OF ACID ON FLAVOR.

Sixteen lots of cheese were made for these experiments. Two lots were made each day from vats of divided milk so as to have identical conditions as regards quality of milk. One of these lots was worked up with just sufficient acid in the whey to make a light-acid cheese, the other lot being worked up on the same day in the regular way for that factory. The cheese maker in charge of this factory set his

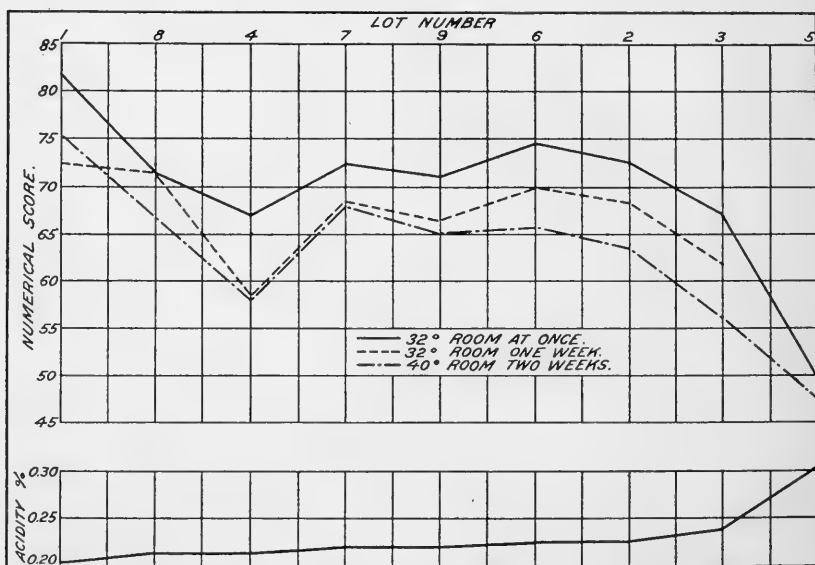


FIG. 1.—Diagram showing relation of acidity to score of cheese at various periods and temperatures.

milk and drew the whey somewhat sweeter than is customary among the best cheese makers; but the curd was allowed to develop the acid on the rack until all danger of gas had passed. Table 5 shows some of the details of the manufacture of each lot.

The cheese was made during the first half of September, 1907, and each lot was held in the factory curing room one week before being placed in storage. The storage room was held at about 33° F. The cheese was scored in the middle of January, 1908, by J. W. Moore and Robert McAdam, of the Dairy Division, both experienced cheese makers and judges. The average score of each cheese is shown in Table 6, and the relation of the numerical score to the acidity is graphically shown in figure 2.

TABLE 5.—*Details of manufacture of cheese for test of high acid on flavor.*

Lot.	Time set.	Acidity when set.	Time cut.	Time drawn.	Acidity when drawn.	Curd ground.	Curd salted.	Remarks.
	<i>a. m.</i>	<i>Percent.</i>	<i>a. m.</i>	<i>a. m.</i>	<i>Percent.</i>	<i>p. m.</i>	<i>p. m.</i>	
1, acid....	7.52	0.17	8.25	11.00	0.23	1.15	1.40	Curd firm; few pin holes; bad flavor.
1, sweet..	7.45	.17	8.25	10.00	.17	12.30	2.15	Numerous pin holes; bad flavor, same as acid vat.
2, acid....	8.30	.20	8.50	9.55	.20	12.20	1.30	Good curd.
2, sweet...	7.20	.17	7.55	9.15	.15	12.30	1.30	Do.
3, acid....	8.10	.20	8.30	9.55	.20	11.45	12.30	Good curd; slight taint.
3, sweet...	7.40	.175	8.20	9.45	.16	12.00	12.30	Few pin holes; slight taint.
4, acid....	7.50	.20	8.20	9.35	.21	12.05	1.00	Gassy.
4, sweet...	7.40	.17	8.20	9.45	.18	12.45	1.30	Do.
5, acid....	10.00	.20	10.20	11.55	.21	2.20	3.30	Slight taint; pin holes.
5, sweet...	8.50	.17	8.45	10.40	.16	1.00	2.30	Do.
6, acid....	8.40	.20	9.02	10.45	.20	1.00	2.15	Do.
6, sweet...	8.00	.19	8.30	10.30	.16	12.40	2.00	Do.
7, acid....	8.52	.20	9.15	10.45	.20	1.00	2.00	Slight taint.
7, sweet...	8.10	.18	8.50	10.50	.18	2.00	3.00	Slight taint; few pin holes.
8, acid....	9.20	.145	9.40	11.30	.19	1.30	2.30	Slight taint; pin holes.
8, sweet...	7.45	.175	8.32	10.45	.16	1.15	2.00	Do.

TABLE 6.—*Average scores of cheese described in Table 5.*

Lot.	Numerical score.						Descriptive score.		
	Acidity when drawn.	Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.	Color.
	<i>Per ct.</i>								
1, acid....	0.23	35½	23½	13½	10	82½	Sour whey, sweet...	Coarse, mealy, stiff.	Acid cut.
1, sweet...	.17	39	28	15	10	92	Sweet.....	Mechanical holes	Straight.
2, acid....	.20	34	24½	13½	10	81½	Sour, bitter, unclean.	Short, pasty, mealy.	Acid cut.
2, sweet...	.15	39	27½	15	10	91½	Unclean.....	Mechanical holes	Straight.
3, acid....	.20	33½	23	13½	10	79½	Very unclean, sweet, sour whey.	Crumbly, mealy....	Acid cut.
3, sweet...	.16	39½	27½	15	10	92	Trifle sweet.....	Coarse.....	Straight.
4, acid....	.21	37½	24½	13½	10	85½	Unclean, sweet.....	Short, mealy.....	Acid cut, slightly.
4, sweet...	.18	39½	27½	15	10	92½	Sweet.....	Coarse.....	Straight.
5, acid....	.21	36	25	13½	10	84½	Sour whey, bitter, sweet.	Crumbly, mealy, salvy.	Acid cut.
5, sweet...	.16	39½	27	15	10	91½	Slightly sweet.....	Uneven.....	Straight.
6, acid....	.20	34½	24	12½	10	81½	Sour whey, bitter, sweet.	Mealy, soggy.....	Acid cut.
6, sweet...	.16	38½	27½	14½	10	91	Sweet.....	Uneven.....	Slightly faded.
7, acid....	.20	36½	26½	14	10	86½	Fermented, sour whey, bitter, sweet.	Short, mealy.....	Acid cut.
7, sweet...	.18	38½	27½	15	10	91	Tainted, sweet.....	Weak.....	Straight.
8, acid....	.19	36½	25½	14	10	86	Sour, bitter, sweet.....	Crumbly, mealy....	Acid cut.
8, sweet...	.16	38½	28½	15	10	92			Straight.

Average score on flavor of cheese made with normal acid, 39.

Average score on flavor of cheese made with high acid, 35.5.

As will be noted from Table 6, the milk was not perfect at any time during which the experimental cheese was made, neither was it very bad, and there was no difficulty in making a cheese that commanded full market price. There was a slight taint, also a few pin holes that worked out easily in the matted curd. It was perhaps unfortunate in some respects that the milk was not perfect for a few of the lots.

But the results of the experiment are so positive that it can not be considered otherwise than conclusive.

A study of the numerical and descriptive scores in Table 6 shows that high acid has a markedly injurious influence on the flavor. The bad flavors in the cheese made up sweet were in every case less pronounced than in that of the same lot which was made up acid. In addition other bad flavors appeared in the acid cheese that were not apparent in the cheese made normally. The sweet or fruity flavor that was noticed in all the cheese was more pronounced in the high acid than in the normal cheese of the same day. In five out of the eight lots a bitter flavor in the acid cheese appeared that was not noticeable in the normal cheese of the same day. A sour or old whey flavor appeared in most of the high-acid cheese.

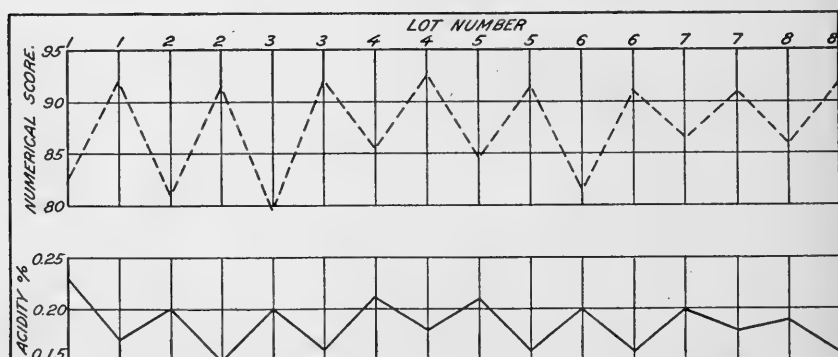


Fig. 2.—Diagram showing relation of acidity to score of high-acid and normal cheese.

#### RESULTS OF EXPERIMENTS CONTRARY TO GENERAL PRACTICE.

These results are certainly very radical in view of the belief of cheese makers and the teaching of experts to the contrary. The great majority of cheese makers believe that a high development of acid is an antidote for bad flavors of all kinds, and that it is about the only means they have of fighting bad flavors as well as gas. Whenever a period of bad milk comes and the product is off flavored or gassy, the effort has always been made to develop a maximum of acid in the whey as a preventive of the trouble. It has, in fact, usually been considered advisable, where the trouble has been pronounced, to make a slightly high-acid cheese, as the high acid has been considered the less of the two evils. This practice is taught by dairy instructors and recommended by many cheese dealers who act as advisers to the cheese makers from whom they buy. The result has usually been that after a few lots of poor cheese were made at a factory a period of high-acid cheese followed. The foregoing experi-

ments prove that this tendency to develop excessive acid is poor policy. In fact, instead of minimizing the faults it makes them more pronounced, as well as adding new faults to the product.

It is universally believed and taught that a maximum development of acid in the whey is necessary for a satisfactory and maximum development of acid in the matted curd. Dean,<sup>a</sup> in some of his work, seemed to show that the curd was ready for grinding and for the press at the same time regardless of the percentage of acidity at which the milk was set or the whey drawn, vats of divided milk being used for the experiments. In view of the fact that the bacteria are held within the curd particles and the acid is consequently developed in the curd, we have no reason to believe that this development would not go on as fast in the matted curd as in the whey. This would appear to be much more reasonable than the old idea that a maximum development of acid in the whey was necessary to hurry the process.

While a high acidity is needed to exclude undesirable forms of bacteria and give the cheese its desired characteristics, this high acidity can develop in the matted curd. That there is no virtue in a high development of acid in the whey can be seen from Table 5. The taint and the gas were as bad in the curd allowed to remain in the whey until a high acid was developed as they were in the curds from the comparatively sweet whey. The development of high acid in the whey did not have any effect on the growth of injurious bacteria, as far as could be judged from the product. The maximum amount of acid in the whey at time of drawing is about 0.2 per cent, and this is generally considered to be insufficient to check most of the injurious bacteria. It is the comparatively high-acid development which takes place in the matted curd that holds these bacteria in check.

From all this evidence there is but one conclusion to be drawn, namely, that the teaching which led to a maximum development of acid in the whey was wrong. The high acid developed in the whey is likely to cause much injury, and from the evidence at hand it does no good. With our present knowledge, however, it can hardly be advised to go to the other extreme and run the whey as sweet as possible, but it is certainly evident that the whey should be run sufficiently sweet to leave no possibility of making a high-acid cheese.

An interesting feature of the results of the experiments shown in Tables 1 and 2 is seen in the lots where only part of the cheese turned out to be high acid. The cheeses in those lots that were placed in storage direct from the press showed no evidence of high acid, while those that remained in the factory curing room for a time before going

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<sup>a</sup> Twenty-second Annual Report, Ontario Agricultural College, 1896, p. 54.

into storage were injured in texture and color. The point in this connection lies in the fact that the cheese that was injured in texture and color was likewise injured in flavor. Whether the low score on flavor was simply coincident with the low score on texture and color and due to the longer time that the cheese was held out of storage, or whether there is some unexplained connection between the injury in texture and the injury to flavor, might seem open to question. It would appear that the former was the case in part. If the latter be true it must be considered that the point in acidity which injures the texture also injures the flavor. There are reasons to believe that this is true, or at least that the point of acidity at which the flavor is injured and the point at which the texture is injured are not very far apart.

There is therefore a question in connection with this which may be investigated with profit. Whey can be drawn with 0.2 per cent of acid without injury to the texture of the curd. Any acid above this evidently injures both texture and flavor. Does the injury to texture and to flavor begin at the same point in acidity, or does injury to flavor begin with a lower acidity than 0.2 per cent?

#### THE USE OF STARTER IN MILK.

Nothing in this discussion should be interpreted as being opposed to the use of a good starter in the milk before setting. The development of acid is, according to our present knowledge on the subject, necessary to overcome the growth of gas-producing and other undesirable forms of bacteria. Bacteriological investigations have shown that if there is a sufficient number of lactic-acid bacteria as compared with the other kinds, the lactic-acid bacteria increase to the partial exclusion of many other kinds. When the lactic acid has developed to a relatively high degree it makes the milk or the curd an unfavorable place for many kinds of bacteria to grow. The starter can be added usually without any danger of increasing the acidity to a point where it will be difficult to cook to a proper degree of firmness before too high acidity has developed in the whey.

#### EFFECT OF EARLY STORAGE ON ACID CHEESE.

This work may be considered a continuation of previous work carried on by the Dairy Division at Plymouth during the summer of 1905.<sup>a</sup> It was planned to determine definitely some of the results which showed incidentally in the previous work. The main point which it was desired to cover was the effect of low storage temperatures on high-acid cheese.

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<sup>a</sup> Bureau of Animal Industry Bulletin 85.

In the report on the previous storage work at Plymouth attention was called to the fact that in two or three lots of cheese used in the tests the cheese which was left in the factory curing room for from one to two weeks at a temperature of from 55° to 70° F. showed decidedly too much acid, almost a so-called "dead sour" in one case. The ones from the same lots (including the dead-sour lot) which went directly from the hoop into the rooms held at 32° and 40° F. were very slightly acid, in fact showed so little evidence of too much acid that the selling price was not affected in the least. This was a decidedly interesting point, and as practically all cheese dealers held entirely opposite views, a thorough demonstration of the results obtained would be of economic importance as well as of scientific value.

At the present time most of the cheese dealers protest against receiving a cheese under one week of age, because in a young cheese too much acid can not be readily detected. If it can be satisfactorily shown that a cheese which does not show too much acid at the time it goes into storage will come out of storage in good condition the objection on the part of the dealers to receiving very fresh goods would be entirely overcome, so far as high acid is concerned.

A reference to Tables 2 and 3, which give details of experiments intended to cover this point, shows that the sooner a high-acid cheese is placed in cold storage the better it is for the cheese. This is borne out by the scoring of the cheese in lot 1. The cheese that was left in the factory curing room for a week before going into storage showed decidedly acid and was badly injured, while that which went directly into storage was not injured in either texture or color. In all the other lots the scores show that the effect of the high acid was minimized by early storage.

The favorable effect that immediate storage has on high-acid cheese was very clearly demonstrated also in Table 1. Lots 4, 12, 14, 15, 16, 19, 20, 22, 26, and 31 described in this table were evidently made up with too much acid. The portions of these lots that remained in the factory curing rooms for any length of time after making showed defects in texture and color, while those that went directly into storage were not injured in the least. The average score on the high-acid lots of the cheese just referred to that went into storage at once was 78, while the average score of the lots that went into storage in one week was 74. Similarly the scores of the lots in Table 2 were 72.5 and 67.2, respectively.

In so-called dead-sour cheese early storage will minimize the damage, but it is not a cure, as is evidenced by lot 5 in Table 3. However, the buyers can usually detect these very sour cheeses at an early age, and there is no danger of deception. From these experiments

it would appear that the objection on the part of the buyers to handling a cheese direct from the press is not well founded.

#### CONCLUSIONS.

1. In the process of making Cheddar cheese a too high development of whey acid injures the flavor as well as the texture of the curd.

2. The development of acid in the matted curd overcomes gas and bad taints and does not injure the flavor and texture.

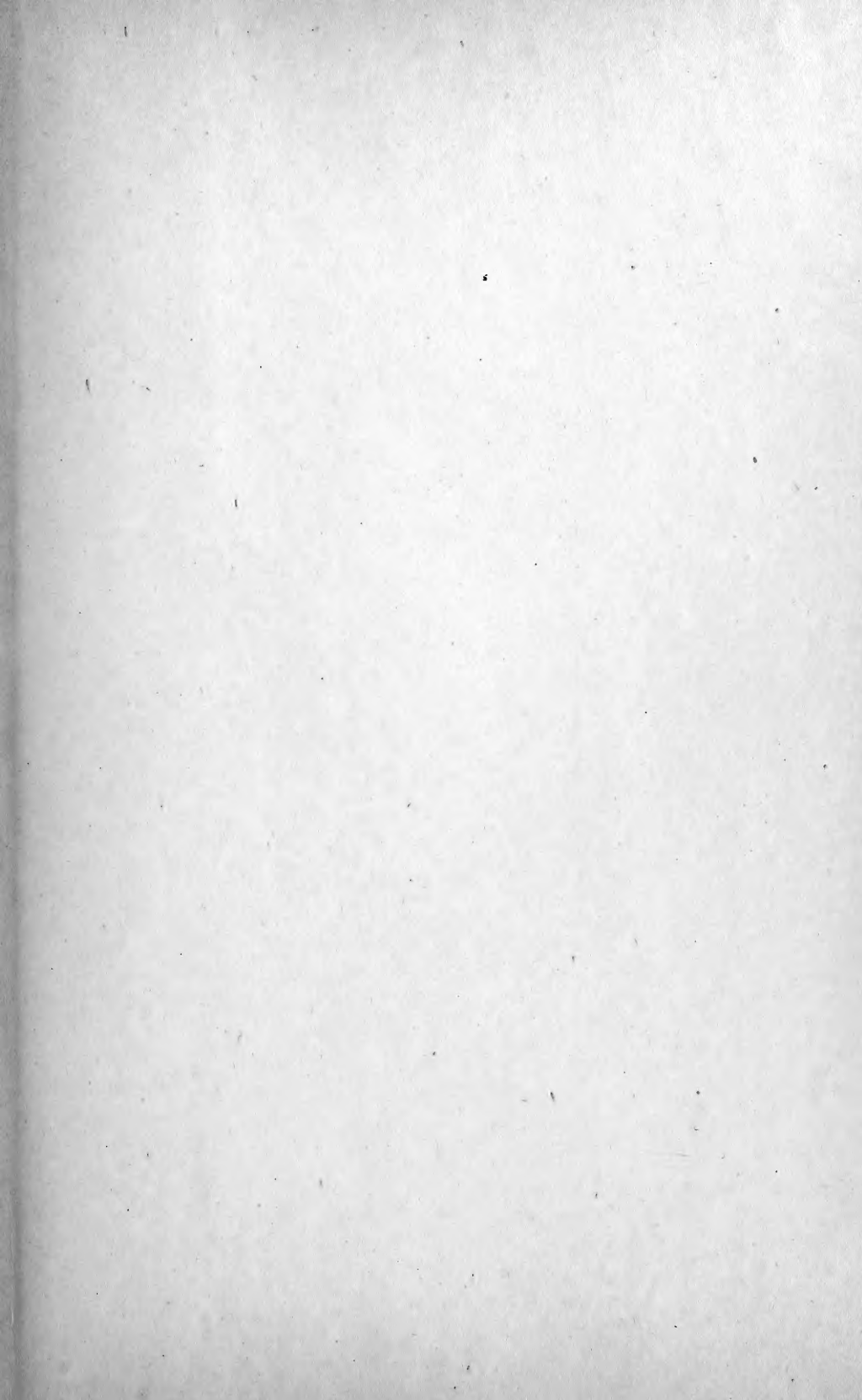
3. Cheese with high acid should be put into cold storage as early as possible to minimize the bad effect of the acid.











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